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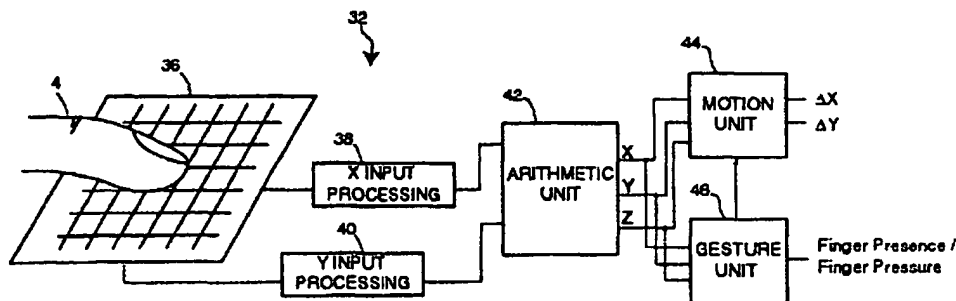
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(54) Title: A FLEXIBLE TRANSPARENT TOUCH SENSING SYSTEM FOR ELECTRONIC DEVICES



(57) Abstract: A transparent, capacitive sensing system particularly well suited for input to electronic devices is described. The sensing system can be used to emulate physical buttons or slider switches that are either displayed on an active display device or printed on an underlying surface. The capacitive sensor can further be used as an input device for a graphical user interface, especially if overlaid on top of an active display device like an LCD screen to sense finger position (X/Y position) and contact area (Z) over the display. In addition, the sensor can be made with flexible material for touch sensing on a three-dimensional surface. Because the sensor is substantially transparent, the underlying surface can be viewed through the sensor. This allows the underlying area to be used for alternative applications that may not necessarily be related to the sensing system. Examples include advertising, an additional user interface display, or apparatus such as a camera or a biometric security device.

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## **A FLEXIBLE TRANSPARENT TOUCH SENSING SYSTEM FOR ELECTRONIC DEVICES**

5

### **BACKGROUND OF THE INVENTION**

#### **Field of the Invention**

10           The present invention relates to touch sensing transducers and systems. More particularly, the present invention relates to flexible and transparent object position recognition devices useful in applications such as cursor movement and user input for computing devices and other applications.

#### **15   Description of the Related Field**

          Touch sensing technology can be used to provide a variety of input to electronic devices, from emulating physical buttons or slider switches to more sophisticated recognition of patterns or gestures. For example, United States Patent No. 5,880,411 to Gillespie, which is hereby  
20   incorporated in its entirety for its teaching of touch sensor technology, discloses a capacitive sensor trace array object position detector with edge motion feature and gesture recognition. United States Patent No. 5,305,017 to Gerpheide teaches an object position detector using capacitive sensing and is also incorporated in its entirety by reference for  
25   its teaching of touch sensor technology. Another example of capacitive touchpads is United States Patent No. 5,543,588 to Bisset.

          However, in many applications it is desirable to display the surface underlying the touchpad. For example, the touchpad can be overlaid on an active display such as a LCD or CRT screen to facilitate input to a  
30   graphical user interface (GUI). Alternatively, it may be desired to have

the underlying surface display static information such as a button pattern to guide user input or advertising. Neither Gillespie nor Bisset disclose or suggest the ability to display a surface underlying the touchpad sensor.

The general strategy employed by the prior art to provide

5 transparent touch sensing technology for portable devices utilizes a resistive pad. A typical resistive pad consists of two substantially transparent substrates separated by a thin air gap, typically about 0.006 inches. One substrate is deformable, such as a polyester film, while the other is typically rigid, such as glass or polycarbonate plastic. Both

10 substrates are coated with a substantially transparent, conductive coating like Indium Tin Oxide on the surface where they face one another. On the ITO-coated surfaces, one substrate contains conductors at its left and right edges while the other substrate contains conductors at its top and bottom. To measure position in one axis, a voltage gradient is applied to

15 one set of conductors while voltage is measured on the other set. When an object deforms the resistive pad so that one substrate contacts the other, the point of contact will contain a voltage proportional to the distance from the conductor where the voltage was applied. To measure position in the other axis, the conductors for voltage application and

20 measurement are switched.

There are other variations of the previously described 4 wire resistive pad sensors. One example is a 5-wire design which alternately applies an X-axis, than Y-axis voltage gradient to the one layer and then uses the second layer simply to sense voltage.

25 Different prior art techniques deal with the difficulty of maintaining a constant air gap between the two ITO layers and the stretching of the deformable substrate as it wears. For example, substantially transparent dielectric spacer dots, usually about 0.010" in diameter, can be arranged in a regular, grid-like fashion over one of the ITO surfaces. These dots

30 help maintain the air gap to prevent the two ITO layers from accidentally

contacting. Further, the dots help counteract the decreasing performance of the deformable substrate as it wears and stretches. However, the use of these spacer dots generally reduces the resolution of the touchpad, as not all locations of such a resistive pad will necessarily generate a signal  
5 when the two substrates come in contact.

In addition to the resistive pad technologies, other examples of prior art include capacitance based technologies, stylus based technologies and pressure actuation technologies. Prior art capacitive touchpads such as United States Patent Nos. 5,457,289 to Huang and  
10 4,806,709 and 4,733,222 to Evans suffer from various drawbacks of their own. For example, Huang requires frontal shielding for its capacitive touch sensor system and the Evans '709 requires a uniformly electrically conductive surface. Stylus based pads such as United States Patent Nos. 5,381,160 to Landmeir and 4,945,348 to Ibamoto require an  
15 electromagnetic tool to provide input. Finally, pressure actuated touchpads such as United States Patent No. 4,484,038 to Dorman and 3,757,322 to Barkan have moving parts and thus suffer from drawbacks similar to the resistive pad technologies.

## 20 **SUMMARY OF THE INVENTION**

The invention is a capacitive sensor system comprising a sensor trace and a processor configured to detect capacitance changes in the sensor trace to determine proximity of a conductive object. Preferably, the sensor trace is a part of a first plurality of sensor traces oriented in a  
25 first direction and the processor detects capacitance changes in the sensor traces to determine proximity and positioning of the finger in the first dimension. More preferably, the system further comprises a second plurality of sensor traces oriented in a second dimension, wherein the processor is further configured to detect capacitance changes in the first  
30 plurality of sensor traces and the second plurality of sensor traces to

determine proximity and positioning of the conductive object along the first and second dimensions. The preferred conductive object for this invention is a human finger, but a conductive stylus or other suitable device can be used as well.

5           To maximize transparency, the sensor system should have a uniform density of sensor traces. Thus, preferred configurations minimize the overlap of the first plurality and the second plurality of sensor traces. For example, each sensor trace may be configured as a series of diamond shapes aligned along a common axis. Accordingly, each plurality of  
10   sensor traces thus creates a pattern of diamond shaped open spaces. By positioning the first plurality of sensor traces over the second plurality so that the diamond shaped sensor traces fall over the diamond shaped open spaces, the amount of overlap between the each plurality of sensor traces is minimized. Transparency is also maximized by utilizing materials  
15   having similar indices of refraction.

          A primary object of this invention is a positioning system that uses a low-cost, highly integrated, low power, capacitive transparent sensor. This invention is suitable for many handheld electronic applications such as, but not limited to, cell phones, pagers, personal digital assistants,  
20   remote controls, and computers. Non-handheld devices that require a positioning system with a thin transparent sensor are also appropriate for this invention. Preferably, the sensor system is equipped with a processor capable of recognizing gestures such as tapping or dragging to increase the flexibility of user input.

25           The current invention described offers a number of advantages over resistive pads and the other prior art technologies. First, this art is rugged. Its performance will not degrade over time and is not subject to mechanical wear and stress, being completely solid state and having no moving parts. Because this art does not rely on deforming a substrate,  
30   the sensor can be activated with no actuation force. Second, the

resolution of sensing is determined by the density of sensor traces and the precision of the A/D converters in the processor, not the physical properties of the materials as in resistive pads. Thus, very high positioning accuracy can be achieved. Because the current invention does  
5 not require an air gap to be maintained between the sensing layers, positioning performance is hardly affected by mechanical damage or environmental conditions such as temperature, humidity or power supply voltage. Consequently, the positioning capabilities of this art require little to no user calibration. Furthermore, the lack of an air gap, with an index  
10 of refraction much different than the substrate layers, allows this art to achieve greater transparency. Finally, the ability to use flexible substrate material to build the sensor facilitates the integration of this art onto devices that require a touch-sensing system on a curved, three-dimensional surface. Alternatively, the sensor array itself can be directly  
15 applied to a rigid, curved three-dimensional surface without the requirement of a flexible substrate.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 shows a schematic representation of a proximity transparent  
20 capacitive sensing system of the present invention.

FIG. 2 shows a cross sectional view of the embodiment of the proximity and one-dimensional sensor transducer shown in Fig.1.

FIG. 3 shows a schematic representation of a one-dimensional transparent capacitive sensing system of the present invention.

25 FIG. 4 shows a schematic representation of a two-dimensional transparent capacitive sensing system of the present invention.

FIG. 5A is a top view of the X sensor array in the embodiment shown in FIG. 4.

FIG. 5B is a top view of the Y sensor array in the embodiment  
30 shown in FIG. 4.

FIG. 5C is a top view of the combined X and Y sensor arrays in the embodiment shown in FIG. 4.

FIG. 6 is a cross sectional view of a two-dimensional sensor transducer embodiment of the invention with a transparent ground plane  
5 to shield X and Y trace arrays from electrical noise that might arise beneath the sensor.

FIG. 7 is a cross sectional view of an alternate embodiment of the two-dimensional sensor transducer of the invention.

FIG. 8 is a cross sectional view of a two-dimensional transparent  
10 sensor transducer embodiment of the invention that allows use of a conductive stylus in addition to finger for input.

FIG. 9 is a cross sectional view of a two-dimensional sensor transparent transducer embodiment of the invention that allows use of any general stylus in addition to finger for input.

15

#### **DETAILED DESCRIPTION OF THE INVENTION**

Figure 1 is a schematic representation of a preferred embodiment of the invention, comprising a 0-dimensional, capacitive proximity sensing system 2. System 2 accurately determines the proximity and contact of  
20 finger 4 or any other conductive object to the sensor 6. Capacitance changes induced by finger 4 on the sensor trace in the sensor 6 are digitized by the input processing block 8. The digitized values of capacitance values are processed by arithmetic unit 10 and then decoded by gesture unit 12 to determine if a finger was present. Gesture unit 12  
25 also processes input signals to determine the difference between constant finger contact and a finger tap. Blocks 8-12 may also incorporate methods to suppress electrical noise that may be sensed by sensor 6. Suitable means of implementing this sensor include the technologies described in United States Patent Nos. 5,880,411 and  
30 5,305,017, which were incorporated in their entirety by reference thereto

above for these teachings. Other means of capacitive sensing technology known to those of skill in the art are also suitable.

The sensor trace in sensor 6 must be designed so that the trace provides adequate capacitive coupling to the finger. In the preferred embodiment, the sensor trace is a thin line of conductor that is drawn to the location where the finger is designed to contact. At this preferred contact area, the trace widens to a square or a circle approximately the dimensions of a typical fingerprint. This ensures that adequate capacitive coupling will occur between the sensor and the finger. Non-visible portions of the sensor can optionally be drawn with an opaque conductor with better handling properties and lower resistance. Examples of an opaque conductor include, but are not limited to, silver ink and conductive carbon ink.

Figure 2 is a cross sectional view of the preferred embodiment of the capacitive sensor 6 (and also one-dimensional capacitive sensor 20 described below). A top transparent and electrically insulating substrate 52 is adhered with an optically transparent and electrically insulating adhesive 54 to another transparent, electrically insulating substrate 58 that is coated with a transparent conductor 56. Typically, the substantially transparent conductor 56 is deposited onto the substrate 58 either by a sputtering process or by a printing method. The pattern of the transparent conductor trace 56 can be done by a photoresist and acid-etch process. Alternatively, conductor 56 may be selectively coated, either by sputtering or printing, onto a negative pattern overlaying the substrate 58. Then, removing the negative pattern leaves the appropriate transparent conductor trace pattern. Because sensor 6 only detects contact and proximity, only one sensor trace and one conductor layer is needed.

Examples of transparent, electrically insulating substrates 52 and 58 include, but are in no way limited to, polyester film, glass, and



polycarbonate plastic. One example of a transparent, electrically insulating adhesive is 3M #8142. Examples of substantially transparent conductors include, but are not limited to, Indium Tin Oxide (ITO), transparent conductive plastic, and silver, gold, aluminum alloys. Those skilled in the art will recognize that no material is completely transparent. To improve transparency of the sensor a number of techniques can be utilized. First, substrates 52 and 58 and adhesive 54 can be chosen to have similar indices of refraction. This improves transparency by minimizing the distorting effects of light traveling through materials of different refraction indices. Second, employing the sensing art described U.S. Patent No. 5,880,411 allows the use of high impedance output drivers. Hence, the resistivity of transparent conductor layer 56 can be relatively high and still be usable with such a sensing system. A high resistivity such as, but not limited to, 300  $\Omega$ /square increases transparency of the substantially transparent conductor layer 56.

Layer 60 shows the location of an opaque substrate that would be viewable through transparent layers 52-58. Examples of such a substrate include, but are not limited to, a graphical display device such as, but not limited to a Liquid Crystal Display (LCD) or Cathode Ray Tube (CRT), artwork, or additional electronics such a fingerprint recognizer. In some embodiments, layer 60 may be omitted altogether. Alternatively, substrate 58 can be omitted and transparent conductor 56 can be patterned directly on layer 60.

In yet other alternative embodiments, layers 52-58 can be reversed without loss of functionality. Furthermore, adhesive 54 can be eliminated so long as substrate 52 is electrically insulating and self-adhering to conductor 56. One example of a self-adhering, transparent, electrically insulating substrate is transparent-coat paint.

Figure 3 shows a schematic representation of a one-dimensional position sensing system 16. Such a system can detect not just finger

contact (like proximity sensing system 2), but also the location of a finger 4 or other conductive object along the direction of the sensor trace array. In Figure 3, sensor 20 contains a plurality of traces oriented along one direction, such as the Y axis, allowing sensing system 16 to determine the position of finger 4 along that direction. Finger location is computed by measuring the capacitance of the traces and then computing finger position based on the increase in capacitance in traces covered or near the finger. Specifically, Y input processing block 22 measures trace capacitance simultaneously in all sensor traces, and digitizes the analog capacitance values. These values are then converted to position and pressure information in arithmetic block 24. Next, position and pressure data are fed into a motion block 26 and gesture block 28. Motion block 26 computes finger motion along the trace array axis based on storing a successive history of finger position values. Gesture block 28 determines if a finger is actually in contact with sensor 20 and whether the finger presence over a short period of time is considered a "tap". If a tap gesture is registered, the gesture unit suppresses the output of the motion unit. Blocks 22-28 also incorporate methods to suppress electrical noise that may be sensed by sensor 20. Suitable algorithms and means for implementing this sensor include the technologies described in United States Patent Nos. 5,880,411 and 5,305,017, incorporated in their entirety by reference thereto as described above. Those skilled in the art will recognize that such algorithms are only illustrative and in no way limiting of the capacitive sensing technology that is possible with this sensor.

The one-dimensional sensor 20 is comprised of a plurality of sensor traces equally spaced along a given axis. To achieve adequate positional resolution, spacing of each sensor trace is typically designed so that a finger 4 covers at least two traces at any given location in the sensing area to allow interpolation between the traces. A higher trace density or

higher precision A/D converters improves the resolution to which sensing system 16 can compute finger position. To maximize capacitive coupling between a trace and a finger, a trace is typically made as wide as possible (for example, slightly less than a trace spacing) without touching  
5 neighboring traces. As described above with respect to the proximity sensing system 2, non-visible portions of the sensor can optionally be drawn with an opaque conductor.

A cross-sectional view of one-dimensional position sensor 20 is shown in Figure 2, previously described. In the preferred, but not limiting  
10 embodiment, the substrate 58 is uniformly coated with the transparent conductor and then the trace array is patterned using a photoresist and acid-etch process. Alternatively, a negative photoresist pattern can be screened on transparent substrate 62 and 68, the transparent conductor deposited using a sputtering or screening process and then the  
15 photoresist pattern removed. As discussed above with respect to the proximity sensing system 2, the stack-up of one-dimensional position sensor 20 comprising layers 52-60 can be reversed and a self-adhering, insulative substrate 52 can obviate the need for adhesive 54.

Figure 4 is a schematic representation of a two-dimensional  
20 position sensing system 32. Such a system can determine finger presence as finger position along two direction axes. Finger 4 capacitively couples to sensor traces in sensor 36. X input processing block 38 and Y input processing block 40 measure capacitance values of sensor traces in the X and Y trace arrays and digitize the capacitance  
25 values. Arithmetic unit 42 computes position and pressure coordinates based on the digitized capacitance values. Next position and pressure coordinates are fed into motion unit 44 and gesture unit 46. Motion unit 44 computes relative movement of the finger compared to the previous position of the finger. Gesture unit 46 determines the finger presence  
30 over time and whether it constitutes a gesture such as a tap. If gesture

unit 46 recognizes a particular gesture, it will suppress the output of the motion unit 44. Blocks 38-46 also incorporate methods to suppress electrical noise that may be sensed by sensor 36. Suitable algorithms and means for implementing this sensor include the technologies  
5 described in United States Patent Nos. 5,880,411 and 5,305,017, incorporated in their entirety by reference thereto as described above. Those skilled in the art will recognize that such algorithms are only illustrative and in no way limiting of the capacitive sensing technology that is possible with this sensor.

10 Figure 5A shows the preferred embodiment for the array of sensor traces used to compute position in the X-axis in sensor 36. Each trace 64 is a transparent conductor, equally spaced on a transparent, electrically insulating substrate 62. Each diamond 66 increases the trace area and also leaves a pattern of diamond-shaped regions containing no  
15 conductive material. Figure 5B is the corresponding preferred embodiment for the array of sensor traces used to compute position in the Y-axis for sensor 36. Each trace 70 is also a transparent conductor, equally spaced on transparent, electrically insulating substrate 68. Diamonds such as diamond 72 increase trace area and leave a diamond-  
20 shaped region where there is no conductive material.

The actual number of sensor arrays and the presence of two axes of sensors will depend on the positioning area and resolution requirements of a particular device. To achieve adequate positional resolution, spacing of each sensor trace is typically designed so that a  
25 finger 4 covers at least two traces in each axis at any given location in the sensing area. A higher trace density or more precise A/D converters improves the resolution that sensing system 32 can compute finger position. In some embodiments of the art, fewer X and Y traces will suffice to achieve the desired sensing resolution. Non-visible portions of

the sensor can optionally be drawn with an opaque conductor such as, but not limited to, silver ink.

In the preferred, but not limiting embodiment, substrates 62 and 68 are uniformly coated with the transparent conductor and then  
5 patterned using a photoresist and acid-etch process. Alternately, a negative photoresist pattern can be screened on transparent substrate 62 and 68, the transparent conductor deposited using a sputtering or screening process and then the photoresist pattern removed.

Figure 5C is a top view of sensor 36 with Y-axis traces from  
10 substrate 68 on top and X-axis traces from substrate 62 on the bottom. X-traces 66 are positioned so that their trace diamonds 72 fill diamond spaces between the Y axis traces 70. For illustrative purposes, Y-axis trace diamonds 72 are reduced in size to visually distinguish the diamonds in the two different arrays. In the preferred embodiment, these  
15 diamonds are enlarged to the size of the spaces between X traces 66 so that sensor 36 appears to have a single uniform layer of transparent conductive material (except for the small regions where an X trace 64 overlaps a Y trace 70). Filling the entire active area with at least one layer of transparent conductor is desirable, but not limiting for the overall  
20 transparency of sensor 36 since transparent conductive material such as (but not limited to) Indium Tin Oxide (ITO), gold, and silver are not perfectly transparent. Any region not covered with at least one layer of conductor in sensor 36 may be seen because it will have greater transmissivity compared to a region covered with a conductor.

25 Figure 5D shows a cross sectional view of the preferred embodiment of two-dimensional sensor 36. This stack-up can be reversed in order without loss of functionality. X-axis transparent, electrically insulating substrate 62 is the top surface that the finger or conductive object touches. The bottom side of the transparent,  
30 electrically insulating substrate 62 is the transparent conductor traces 64.

A thin, transparent, preferably adhesive, insulator 74 separates X conductive traces 64 from Y conductive traces 70. Similar to X traces, Y conductive traces are coated on transparent, electrically insulating substrate 68.

- 5           Examples of transparent substrates 62 and 68, insulator 74, and conductive layers 64 and 70 have been described for Figure 2 and are equally applicable for the two-dimensional sensor. Similarly, the same techniques to improve transparency such as, but not limited to, matching indices of refraction among layers, and using a relatively thin layer of
- 10 transparent conductor, can also be applied to the two-dimensional sensor. Similar to Figure 2, layer 60 is an optional opaque layer that can be viewed through the transparent sensor. . In some embodiments, layer 60 may be omitted altogether. Alternatively, in some embodiments, substrate 68 can be omitted and transparent conductor 70 can be
- 15 patterned directly on layer 60.

A number of additional alternative embodiments of the invention are possible. For example, electrical shielding may be required to isolate sensor traces from electrical noise that arises from electrical circuits that are present below the sensor. One preferred, but not limiting  
5 embodiment is shown in Figure 6 on two-dimensional sensor 36. Layers 62-68 are the same art as described in Figure 5D. Beneath transparent substrate 68, another layer of transparent insulator 74 attaches another layer of transparent conductor 78 and substrate 80. Unlike transparent conductor layers 64 and 70, transparent conductor 78 is a uniform layer  
10 of conductor that is connected to an electrical ground. Grounding transparent conductor 78 provides sensor 36 with electrical shielding from electrical noise sources that might radiate from the opaque layer 60 or below. Examples of materials suitable for transparent conductor 78 and substrate 80 have already been described in Figure 2.

15 Adding a transparent ground plane using layers 74-80 can also be applied to the contact and one-dimensional sensor stack-ups shown in Figure 2 if such a layer were inserted between layers 58 and 60.

In yet another embodiment, Figure 7 shows a two-dimensional transparent capacitive sensor 36. Transparent substrate 84 is adhered  
20 using transparent insulator 74 to transparent conductor layer 64. Transparent conductor 64 contains the X trace pattern as shown in Figure 5A and is coated onto transparent substrate 86. On the other surface of transparent substrate 86, transparent conductor layer 70 contains Y trace array shown Figure 5B. Finally, transparent substrate 88  
25 is adhered to transparent conductor 70 with transparent insulator 74. This particular embodiment, with substrate 86 coated on both sides with transparent conductor layers may allow for less error when aligning diamonds in the X trace array and the Y trace array. Because substrate 86 contains both conductor layers 64 and 70, the alignment of trace  
30 arrays can occur prior to the etching/deposition of the trace arrays with

the opaque photoresist pattern, greatly simplifying pattern alignment of X and Y traces. Proper alignment of the X and Y trace arrays is critical to the overall transparency of two-dimensional sensor 36 because the human eye can easily detect any systematic misalignment between the trace array patterns.

Examples of transparent, electrically insulating substrates 84,86, and 88 have been described in previous embodiments of two-dimensional sensor 36 and one-dimensional sensor 20. Additionally, for electrical shielding, transparent substrate 88 can be replaced with layers 78 and 80 as shown in Figure 6.

This invention may also be adapted for use with a stylus in addition to the human finger. One method for doing so is to enlarge the contact area for a conductive stylus until its contact area is similar to that of a finger. This has the obvious disadvantage of the stylus needing to be both conductive and the contact area needing to be large enough to capacitively couple to enough sensor traces. To reduce the contact area of the conductive input, one method is to increase the trace density so that even a fine, pointed conductive stylus can capacitively couple to at least two sensor traces. Alternatively, A/D converter precision can also be increased to detect minute capacitance changes in sensor traces that result from a pointed stylus.

One preferred alternative method that removes the restriction of a large contact area involves a resistive transparent coating applied to the top surface of the sensor array, resulting in the stack-up of layers shown in Figure 8. For two-dimensional position sensor 92, the X and Y trace arrays are identical to that described in Figures 5A, 5B, and 5C. The stack-up of layers 62-68 is identical to that described in Figure 5D. Layer 94 is a rugged, resistive transparent coating that spreads the effective contact area of a pointed stylus, thus allowing a pointed stylus's capacitive coupling to the sensor 92 to be similar to a conductive object



with a larger contact area (such as a finger). Examples of such a layer 94 can be found, but are not limited to, those commonly used for electro-luminescent lighting surfaces. Further details of such a sensing technology can be found in co-pending United States Patent Application  
5 Serial No. 09/176,639.

An approach for a two dimensional sensor that accepts *any* stylus input is to include a transparent, deformable layer sandwiched between the bottom sensor array layer and a ground plane. Figure 9 illustrates the stack up of a preferred but not limiting embodiment of such a sensor 92.  
10 Layers 62-68 are the same as those described for a finger input two-dimensional sensor 36 as described in Figures 5A-D. The only additional requirement for this art is that substrates 62 and 68 be flexible and deformable. An example of such a substrate is, but is not limited to, polyester film.

15 Beneath transparent substrate 68 is transparent insulator 74. This adheres to a transparent, deformable dielectric layer 96. Another layer of transparent insulator 74 adheres deformable layer 96 to a transparent, conductive layer 78 and transparent substrate 80. Transparent substrate 80 is typically made of a rigid material. Examples of such a transparent  
20 rigid substrate include, but are not limited to, glass and polycarbonate plastic. Transparent conductive layer 78 is a uniform layer of transparent conductor that is electrically grounded.

Functionally, a pointed stylus input will deform the X and Y sensors in layers 62-68 as well as layer 96, bringing the point of contact closer to  
25 the ground plane. This deformation increases the capacitive coupling to ground for sensor traces near the point of contact. This capacitance increase is then detected by the sensing electronics. For finger input, capacitance is sensed by sensor layers 62-68 using traditional capacitive means. A detailed description of this art, though not in a transparent

embodiment, can be found in U.S. Patent No. 5,942,733, which is hereby incorporated in its entirety by reference thereto.

Yet another alternative method is to combine the transparent capacitive finger sensor of the present invention with a second  
5 independent stylus input device. For example, a flexible transparent capacitive pad could be overlayed on a conventional resistive pad to provide superior finger sensitivity to that achievable with a resistive pad alone. Or, a transparent capacitive pad could be overlayed on a solid  
10 state sensor such as an inductive stylus sensor (*e.g.*, U.S. Patent No. 4,848,496 to Murakami, hereby incorporated by reference thereto for this teaching) to produce a rugged sensor with high quality finger and stylus performance.

The transparent position sensing system has a number of applications for portable electronic devices. Some examples (but not an  
15 exhaustive list) of applications include:

a) Pointing device for a touchscreen in a handheld electronic device. In the simplest implementation, a transparent two-dimensional capacitive sensor is affixed directly on top of a display device like an LCD screen to detect a finger's location on the display. The X-Y position of a  
20 finger atop the sensor (and thus, the display) can then be fed to the device's main processing unit to control the user interface in the device. Such a user interface could include, but is not limited to, the control of a cursor on the screen, detection of taps for on-screen graphics that represent buttons, control of on-screen scroll bars, pull-down menu  
25 selection, and stroke or gesture recognition for text-entry.

b) Input device for a soft button array or scroll bar. In this application, the transparent sensor covers only the portion of the display device that is dedicated to displaying an array of buttons or a scroll bar. For a scroll bar application or a one-dimensional button array, the  
30 transparent sensor would only contain a plurality of sensor traces in one

axis. By implementing the input device with a transparent sensor, the underlying graphics can change to suit the functionality required by the user interface

5 c) Integration of input devices in a handheld electronic device. For some handheld devices, one surface of the device may contain a display that requires a touch sensitive positioning system while another surface may require a button array. Because this art can be made from transparent, flexible material, the same capacitive sensor could be curved over the handheld device so that one portion of the sensor's trace arrays  
10 covers the display surface while another portion of the sensor serves as the button array on another surface. This could reduce the cost of the handheld device by eliminating the need for additional mechanical contact switches.

d) Transparent sensor for portable computer. The transparent  
15 nature of the transparent two-dimensional position sensor allows the addition of apparatus for applications such as, but not limited to security and video to be designed into portable personal computers without consuming more real estate than a standard, opaque two-dimensional position sensor. In the case of security applications, the pointing nature  
20 of the touchpad is a logical location to embed a fingerprint-based security system. Other biometric security systems such as a retinal scanner can also be placed underneath the transparent touchpad. The electronic sensor for the biometric system can be located underneath the sensor array (*i.e.* layer 60 in Figures 2 and 5D) and will be minimally affected by  
25 the transparent sensor. Also, the transparent nature of the touchpad is also a reasonable location for a video camera since the touchpad surface protects the camera from the environment

e) Graphic underlays beneath the transparent capacitive sensor (other than a display device). In some applications, the use of a display  
30 device such as an LCD screen may not be necessary or cost-effective. In

such applications, a simple graphic underlay such as a plastic button template could be slid into a slot underneath the transparent sensor. Advertising logos or other graphics not related to the device user interface could also be placed under the sensor.

- 5           f) Display-enhanced capacitive sensor for a personal computer. To enhance the user interface for personal computers, the transparent two-dimensional sensor can be used in conjunction with an underlying LCD display device for a display-enhanced sensor input device. The underlying LCD screen can provide information such as a record of the current stroke  
10 or gesture for handwriting recognition, signature/text capture or graphics software. Soft buttons, icons, scroll bars, or other zones of enhanced sensor functionality could also brought to attention on the LCD screen. In more general terms, a display-enhanced sensor could contain specific applications that interface with the host computer. Examples include, but  
15 are not limited to, mimicking a numeric keypad, launching applications, or providing menus or soft buttons that are specific to a software application that is running concurrently on the host computer. Finally, advertising logos, or bitmapped images and photographs can be drawn in the LCD screen to enhance functionality or as additional display space.
- 20           g) Display-enhanced capacitive sensor for personal computer that detaches to function as a stand alone handheld device. A further extension of the display-enhanced sensor is a detachable transparent sensor and LCD display assembly. While the sensor and LCD is attached to the host computer, it functions as a display-enhanced sensor as  
25 described in the previous section. However, the sensor and LCD assembly also contains hardware and software to function as a stand alone, handheld device, for example, a personal digital assistant (PDA) device such as a 3Com PalmPilot™ or a Rolodex Rex™. The detachable sensor has distinct benefits. First, it serves as a simple security  
30 mechanism for the host computer since most modern computer operating

systems are almost impossible to use without a pointing device. Second, the detachable capacitive sensor provides an obvious location to store the PDA without need for a separate cradle or docking station. Because the input is a capacitive position sensor, the finger pointing performance of such a device is the same as the current state-of-the-art computer touchpads and vastly superior to the resistive pads that are currently in use on most PDA devices.

h) Transparent capacitive sensor as an aesthetic improvement to personal computer design. In some modern computers, transparency is used for purely aesthetic or artistic purposes. A transparent sensor array allows industrial designers to incorporate a pointing device onto a computer but allow the surface underneath to be viewable. This might allow the underlying electronics of the computer, or other artwork such as, but no limited to, logos, advertising, or labels, to be viewable.

Described herein is a preferred embodiment, however, one skilled in the art that pertains to the present invention will understand that there are equivalent alternative embodiments.

**What is claim d is:**

1. A capacitive sensor system comprising a substantially transparent sensor trace and a processor configured to detect a capacitance change in the sensor trace caused by the proximity of a conductive object adjacent to the sensor trace to determine proximity of the conductive object.
2. The capacitive sensor system of claim 1, further comprising at least one additional transparent sensor trace resulting in a first plurality of sensor traces oriented in a first dimension, wherein the processor is further configured to detect capacitance changes in the first plurality of sensor traces corresponding to a conductive object adjacent the sensor traces to determine proximity of the conductive object and positioning of the conductive object along the first dimension.
3. The capacitive sensor system of claim 2, further comprising a second plurality of sensor traces oriented in a second dimension, wherein the processor is further configured to detect capacitance changes in the first plurality of sensor traces and the second plurality of sensor traces corresponding to a conductive object adjacent the sensor traces to determine proximity of the conductive object and positioning of the conductive object along the first dimension and the second dimension.
4. The capacitive sensor system of claim 3, wherein the first dimension is substantially perpendicular to the second dimension.

5. The capacitive sensor system of claim 3, further comprising a substantially transparent insulating material separating the first plurality of sensor traces from the second plurality of sensor traces.
- 5 6. The capacitive sensor system of claim 3, wherein the first plurality of sensor traces and the second plurality of sensor traces are configured to minimize overlap.
7. The capacitive sensor system of claim 6, wherein each  
10 sensor trace of the first plurality of sensor traces and the second plurality of sensor traces is configured to comprise a series of diamond shapes aligned and connected along a common axis.
8. The capacitive sensor system of claim 7, wherein the first  
15 plurality of sensor traces and the second plurality of sensor traces are aligned to maximize transparency.
9. The capacitive sensor system of claim 3, further comprising a flexible substrate.  
20
10. The capacitive sensor system of claim 5, wherein the sensor traces and the insulating material have similar indices of refraction.
11. The capacitive sensor system of claim 1, wherein the  
25 sensor trace is mounted over an active display.
12. The capacitive sensor system of claim 2, wherein the sensor trace is mounted over an active display.

13. The capacitive sensor system of claim 3, wherein the sensor trace is mounted over an active display.

14. The capacitive sensor system of claim 1, wherein the processor is further configured to recognize gestures.

15. The capacitive sensor system of claim 2, wherein the processor is further configured to recognize gestures.

16. The capacitive sensor system of claim 3, wherein the processor is further configured to recognize gestures.

17. The capacitive sensor system of claim 3, wherein the sensor traces are mounted over a system to read fingerprints.

18. The capacitive sensor system of claim 1, further comprising a substantially transparent ground plane to electrically shield the sensor system.

19. The capacitive sensor system of claim 2, further comprising a substantially transparent ground plane to electrically shield the sensor system.

20. The capacitive sensor system of claim 3, further comprising a substantially transparent ground plane to electrically shield the sensor system.

21. The capacitive sensor system of claim 3, wherein the sensor system is mounted over a display device and comprises an object



positioning system in which the display device provides additional user interface information.

22. The capacitive sensor system of claim 8, wherein the first  
5 plurality of sensor traces and the second plurality of sensor traces comprises a sensor array that has substantially uniform transparency.

23. The capacitive sensor system of claim 3, wherein the is  
further configured to detect capacitance changes in the first plurality of  
10 sensor traces and the second plurality of sensor traces to determine contact area of a conductive object.

24. The capacitive sensor system of claim 2, wherein the  
sensor traces are mounted over a system to read fingerprints.  
15

25. The capacitive sensor system of claim 1, wherein the  
sensor traces are mounted over a system to read fingerprints.

26. The capacitive sensor system of claim 1, wherein the  
20 conductive object is a human finger.

27. The capacitive sensor system of claim 2, wherein the  
conductive object is a human finger.

28. The capacitive sensor system of claim 3, wherein the  
25 conductive object is a human finger.

29. The capacitive sensor system of claim 2, further comprising  
a flexible substrate.  
30

30. The capacitive sensor system of claim 1, further comprising a flexible substrate.

31. The capacitive sensor system of claim 1, wherein the  
5 conductive object is a stylus.

32. The capacitive sensor system of claim 2, wherein the conductive object is a stylus.

10 33. The capacitive sensor system of claim 3, wherein the conductive object is a stylus.

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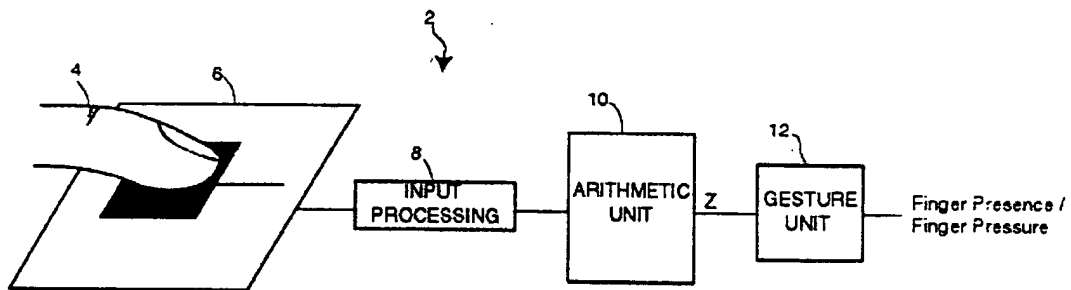


Figure 1

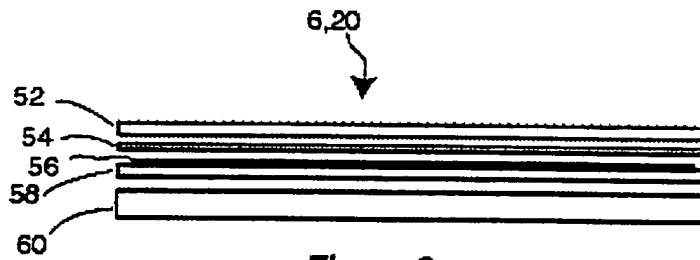


Figure 2

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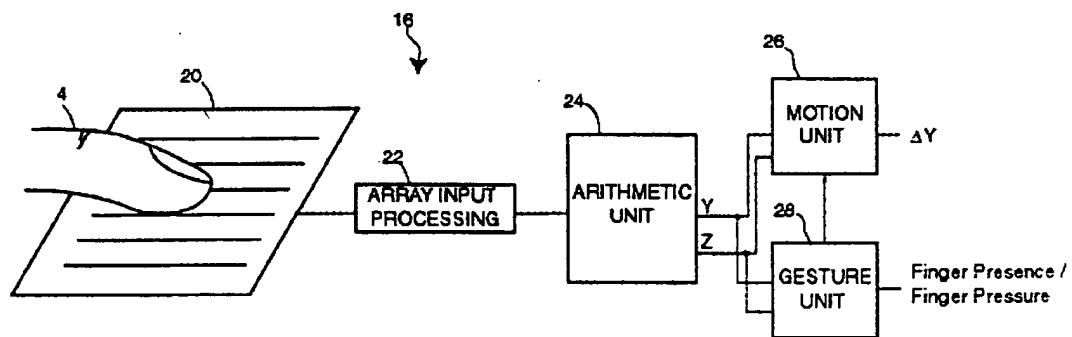


Figure 3

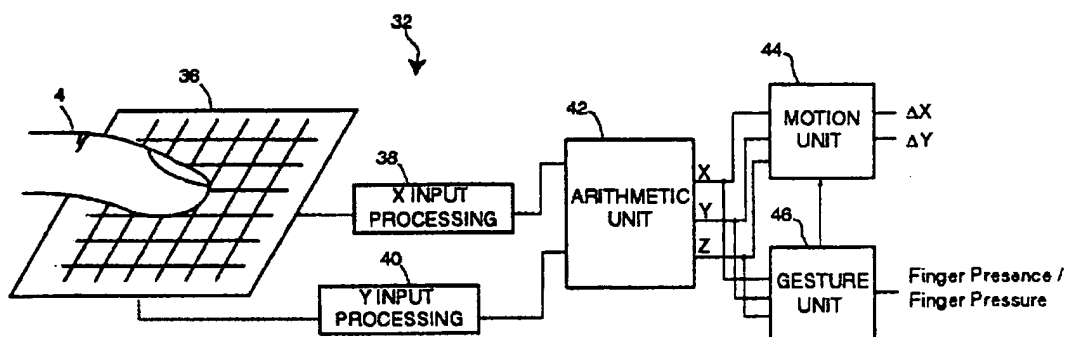


Figure 4

# INTERNATIONAL SEARCH REPORT

Int'l. Application No  
PCT/US 00/27720

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 7 G06K11/16 G06F3/00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 G06K G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, IBM-TDB

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 543 588 A (ALLEN TIMOTHY P ET AL) 6 August 1996 (1996-08-06) cited in the application  column 9, line 13 -column 10, line 26 figures 1A-1D	1-8, 11-13, 21-23, 26-28
Y		9,14-20, 24,25, 29-33
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

16 February 2001

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Int'l. Application No  
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Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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